LEVEL II

6 B.S.

CHANGES IN MOOD, FATIGUE, AND WORK-REST CYCLES ASSOCIATED WITH DEEP SUBMERSIBLE OPERATIONS

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ABSTRACT

As deep submergence vehicles (DSVs) develop greater depth capabilities and are given longer duration missions, the physiological and psychological well-being of the operators and surface support personnel (SSP) becomes of increasing importance in insuring successful completion of the task. Establishment of baseline data on stress and fatigue in submersible operators and SSP is important in determining the safety of present operations and the reserve capability available in the event of present operations and the reserve capability available in the event of unanticipated demands on performance. To obtain information on mood, fatigue, and work-rest cycles of both submersible operators and surface support crew members during actual operational dives in the open sea, 7 operators and 18 SSP were monitored during two separate multi-week evolutions using the DSVs TURTLE and SEA CLIFF. Operators and crew members lived aboard the surface support ship MAXINE D and 15 dives, some in excess of 6,000 FSW, were made. Demographic information, psychological, physiological and performance measures, and environmental data were obtained during pre-deployment, transit-out, dive, nondive, transit-in and post-deployment periods. The results suggested that disruptions in sleep-wake cycles caused by repetitive deep submersible operations may impair accuracy and efficiency on a variety of mental and physical tasks.

INTRODUCTION

As deep submergence vehicles (DSVs) develop greater depth capabilities and are given longer duration missions, the physiological and psychological well-being of the operators and surface support personnel (SSP) becomes of increasing importance in insuring successful completion of the mission. Thus the establishment of baseline data on stress and fatigue in submersible operators and SSP is important in determining the safety of present operations and the reserve capability available in the event of unanticipated demands on performance.

During open sea saturation diving operations, significant increases in sleep loss, fatigue, and mood disturbance among both divers and support personnel have been documented (Townsend and Hall 1977; LeMaire et al. 1978). While operations involving deep submersibles differ in many respects from saturation diving situations, a number of the fundamental causes of psychological and physiological stress and disruption of normal sleep-waking rhythms are still present. These may be potentiated by the greater duration and repetitive nature of submersible operations.

There is presently little data available on the work, sleep disruption, and psychological and physiological stresses placed on submersible operators and SSP (Hall and Linaweaver 1974). However, data from a number of other situations have clearly demonstrated that disruptions in sleep-wake cycles impair the accuracy and efficiency with which a variety of mental and physical tasks can be performed (e.g., see Colquhoun 1971). Such disruptions in the sleep-wake cycles have been documented during even short duration saturation diving operations (Townsend and Hall 1977), and anecdotally reported to occur during sustained DSV operations.

The purpose of the present study was to obtain information on mood, fatigue, and work-rest cycles of both submersible operators and surface support crew members during actual operational dives in the open sea during two separate multi-week DSV evolutions.

METHODS

Seven experienced U.S. Navy submersible operators and 18 U.S. Navy SSP were studied during two separate multi-week deployments using the DSVs TURTLE and SEA CLIFF. These identical 1 ATA submersibles were manufactured by the Electric Boat Division of General Dynamics Corporation and have been operated by the Navy since launched in 1968. Their missions involve search, survey and salvage.

They are 7.9 m (26 ft.) long, 3.7 m (12 ft.) wide, 3.7 m (12 ft.) high and weigh 25 tons in air. The pressure hull is a single sphere 2.1 m (7 ft.) in diameter and can accommodate a crew of three. All necessary operation, control and monitoring equipment is contained within this sphere.

In terms of life support, O_2 is carried inside the pressure hull. CO_2 is routinely removed by scrubbing through LiOH. O_2, CO_2, temperature, humidity and pressure are monitored continuously. The maximum operating depth is 1,981 m (6,500 ft.) and normal mission time is 6 to 8 hours, limited by the main power supply.

The first deployment was 46 days. It consisted of 6 days transit-out; on-scene time divided into 18 non-dive days, 4 diving days, 4 abort-dive days (dive aborted due to equipment failures or weather conditions); in port (on location) 8 days and transit-home 6 days.

The second deployment was 53 days. It consisted of an 8 day baseline pre-deployment period; 2 day transit-out; on-scene time divided into 10 non-dive days, and 9 diving days; in port (on location) 11 days, transit-home 4 days and post-deployment period of 9 days. For both evolutions, the operationally defined multi-day periods composed from the on-scene and in-port days were not necessarily confined to consecutive days. Thus grouping of these data according to operational activities was done to make for meaningful analysis.

The biomedical investigation was divided into two major parts. Part One of the study involved both the vehicle operators and crew members and the following data were collected for the entire length of the deployment:

Demographic Information.

At the beginning of the data collection period, each participant was asked to complete a brief questionnaire designed to provide background information on age, education, and experience in submersibles and diving. Included were questions dealing with crew position, number of previous dives, submersible accidents, and diving or submersible-related medical problems.

Psychological Measures.

NHRC Sleep Log: The NHRC Sleep Log is a daily record of subjective evaluation of sleep. Included are self-ratings of difficulty falling asleep, time taken to fall asleep, number of awakenings, need for additional sleep, degree of restedness following sleep, number of hours of work in the previous 24 hours, and the clock time of sleeping and waking during the previous 24 hours. The sleep log was based on a similar instrument

developed by Hartman and Cantrell (1967) and has been used in diving studies (Naitoh, Johnson, and Austin 1971) to monitor work-rest cycles.

Stanford Sleepiness Scale (SSS): The SSS is a 7 statement self-rating scale to describe alertness and ability to function, ranging from alert, wide awake, to unable to remain awake (Hoddes, Zarcone, Smythe, Phillips, and Dement 1973).

NHRC Mood Questionnaire: The Mood Questionnaire is a 40-item, 3-point adjective rating scale which provides information on the six scales of Happiness, Activity, Fear, Anger, and Fatigue (Ryman, Biersner, and LaRocco 1974). This questionnaire has been used to monitor mood changes in similar field studies (Biersner et al. 1974; McHugh et al. 1974) where work-stress and fatigue were present.

Part Two of the study involved only the submersible operators from whom the following data were collected:

Four-Choice Reaction Time Performance: The Four-Choice Reaction Time Task (Wilkinson and Houghton 1975) is a modified cassette recorder with four stimulus lights and four corresponding response buttons. The task is to press the button corresponding to the stimulus light that is on. Each response turns off the light that is on and causes another light to come on in a random order. The operator's task was to push the button corresponding to each light that came on as quickly as possible without making mistakes for a five minute period. Reaction times and errors were recorded on the self-contained cassette tape. Four-choice reaction time performance was obtained at the pre-dive, bottom-time, and post-dive points for each individual submersible dive. Other studies have shown the four-choice to be sensitive to performance decrements resulting from sleep loss, alcohol, and drug effects (Church and Johnson 1979; Seales, Naitoh, and Johnson 1978; Naitoh et al. 1979).

Physiological Measures.

Heart Rate: Successive one minute samples of resting heart rate were obtained from each of the submersible crew members during pre-dive, dive, and post-dive periods. Heart rate was obtained with a Lafayette Instruments digital heart rate monitor, accurate to $\pm$ 1 BPM in the range 20-200 BPM. This device uses a photoplethysmograph allowing extreme ease of successive sampling from several subjects by the submersible crew themselves with minimal training. Heart rate measures were intended as a rough estimate of work stress (Ackies and Wright 1978).

Oral Temperature: Estimates of core temperatures were obtained pre-, during,

and post-dive for signs of heat or cold stress using an Ivac oral thermometer.

Environmental Data.

The internal environment of the submersible was monitored by existing sensors. These data included PO_2, PCO_2, temperature and humidity. Additionally, daily evolution data including the events which occurred during the normal daily routine (including pre-, during and post-dive occurrences) were recorded to further enhance the interpretation of the above biomedical data.

Analysis.

Of the above measures, the sleep and mood data were collected on a daily basis when possible and a mean measure was obtained on each subject for each of the operational phases. These data were analyzed by the Standard Biomedical Program ANOVA for repeated measures. The more conservative Geisser-Greenhouse test was also applied to adjust for any correlated means. Analysis of the physiological and environmental measures obtained during the individual dives was not necessary while the fragmentary nature of the four-choice data collected only during Evolution II prevented meaningful statistical examination.

RESULTS

EVOLUTION I

The first deployment off the coast of Hawaii was interrupted almost immediately by a transit to Wake Island to search for portions of a downed aircraft in approximately 2,000 FSW. Five dives were conducted and specific portions of the aircraft were located. An extensive photo survey of the debris field was also accomplished during these dives. Due to unfavorable weather and hazardous conditions created by the underwater terrain the operation was terminated. Because of the above conditions and the limited number of dives, only Part One of the biomedical study was completed during this first deployment period.

During a typical diving day most crew members worked a minimum of 12 hours. Operators were generally occupied with submersible dive planning and coordination with the surface support ship. Some of these operators acted as topside control and coordinated the submersible dive from the surface, while others interfaced with SSP. Because of the number of uncontrollable variables included in these operations such as weather, equipment breakdowns and multi-unit coordination, the discreet day/night 24 hour time periods often ran beyond the normal limits. Table 1 provides details of the dives conducted.

Demographic Information.

Twelve subjects participated in Evolution I. The demographic data indicated that, among the DSV TURTLE personnel, there was little intracrew variability except in the area of the number of previous submersible dives logged with this particular vehicle (mean = 9.8, S.D. = 15.3). The mean age was 30.3 years (S.D. = 5.7) while the average education was 12.5 years (S.D. = 1.2). These subjects had worked with submersibles an average of .9 years (S.D. = .7) with a mean of .7 years (S.D. = .6) on the DSV TURTLE crew. Forty-two percent of the subjects reported experience with two or more near accidents or emergency conditions in submersible vehicles but there were no significant histories of submersible or diving related medical problems.

Psychological Measures.

Sleep Log: Table II shows the means and standard deviations for the Sleep Log variables affected by the different phases of the operation. The major changes in sleep occurred during the Dive and Abort-Dive phases, with fragmentation of the sleep-wake cycle and reduced sleep time, and decreased feelings of restedness. There was also an increase in the number of hours worked in each 24 hour period.

Stanford Sleepiness Scale (SSS): There were no significant changes in the SSS (Table II). However, the trend of changes was consistent with the sleep loss indicated on the Sleep Log.

NHRC Mood Questionnaire: Results of the analysis of the NHRC Mood Questionnaire data are shown in Table III as the means and standard deviations for each mood variable for each phase of data collection. Though the conservative Geisser-Greenhouse test indicates that there were no statistically significant changes, the Dive phase appeared to be the most disruptive of the six periods.

Environmental Data.

PO_2, PCO_2, temperature, and humidity were all within normal limits and did not show changes which would be expected to influence physiological or psychological function.

EVOLUTION II

This operation took place in the Gulf of California and was mainly of an oceanographic nature. Ten dives were conducted which included photo surveying of submarine lava areas and gathering rock samples. During this deployment,

Parts One and Two of the study were conducted. Unexpected weather conditions and equipment failures occurred which caused some interruption of the planned diving schedule.

During a typical diving day most crew members worked a minimum of 13 hours. Operators were generally occupied with submersible dive planning and coordination with the surface support ship. As in Evolution I, some of these operators acted as topside control and coordinated the submersible dive from the surface, while others interfaced with SSP. Because of the number of uncontrollable variables included in these operations such as weather, equipment breakdowns, and multi-unit coordination, the discreet day/night 24 hour time periods often ran beyond the normal limits. Table IV provides details of the typical dives conducted.

Demographic Information.

Thirteen subjects participated in Evolution II. The demographic data for the DSV SEA CLIFF personnel indicated little intracrew variability except in the area of the number of previous submersible dives logged with this particular vehicle (mean = 11.2, S.D. = 23.2). The mean age was 30.1 years (S.D. = 5.0) while the average education was 13.9 years (S.D. = 1.9). These subjects had worked with submersibles an average of 1.1 years (S.D. = 1.3) with a mean of .7 years (S.D. = .5) on the DSV SEA CLIFF crew. Twenty-three percent of the subjects reported experience with two or more near accidents or emergency conditions in submersible vehicles but there were no significant histories of submersible or diving related medical problems.

Psychological Measures.

Sleep Log: Table V shows the means and standard deviations for the Sleep Log variables affected by the different phases of the operation. The major changes in sleep occurred during the Dive phase, with reduced sleep time, decreased feelings of restedness, and an actue increase in the number of hours worked in each 24 hr period. These changes were greatly in contrast to the Transit-Out phase which showed increased sleep time, increased feelings of restedness, and a 6 hour decrease in the mean number of hours worked per 24 hour period.

Stanford Sleepiness Scale (SSS): According to the more conservative analysis, there were no statistically significant changes on the SSS (Table V). However, the trend of the changes noted were consistent with the sleep loss indicated on the Sleep Log.

NHRC Mood Questionnaire: Results of the analysis of the NHRC Mood Questionnaire data are shown in Table VI as the means and standard deviations for each mood variable for each phase of data collection. According to the more conservative analysis, only changes in fatigue reached statistical significance, being lowest during the Transit-Out phase. Thus, in terms of mood variation, the Transit-Out, Dive, and Predeployment phases appeared to be the most affected.

Four-Choice Reaction Time: Measurements were taken under the existing conditions and no constraints were placed on the operation to aid in the data collection. Because of the unpredictable nature of the operation, it was impossible to obtain an equal number of measurements on each subject, and only partial data were attainable on some of the dives. Though a meaningful statistical analysis is precluded by such conditions, the data reflect the expected trends. Correct reaction time was relatively stable throughout the dives, while the number and standard deviation of incorrect responses and gaps increased during the mid and end-dive phases.

Physiological Measures.

Heart Rate and Oral Temperature: No significant changes in heart rate were noted. However, changes in the DSV operator's oral temperatures, calculated from pre-dive and end-dive measurements, showed a mean of $-.54^{\circ}C$ with a σ of $.51^{\circ}$ and a range of $2.0^{\circ}C$. These short-term changes alone are not considered to represent a significant limitation on performance abilities or a hazard to the physiological well-being of the crew.

Environmental Data.

PO_2, PCO_2, temperature and humidity were all within normal limits and did not show changes which would be expected to influence physiological or psychological function.

DISCUSSION

Based on these data, we can now describe the typical medium-duration, multiple dive submersible evolution in terms of mood and work-rest cycles. The overall results of the study clearly confirmed the moderately disruptive effects of such evolutions on sleep and mood. As expected, the Dive and Transit-Out phases appear to be the most disruptive of the operational phases. However, the data suggest that performance levels can be adequately maintained during missions of similar duration and difficulty.

Not unexpectedly, in both Evolution I and II, increased workloads in dive preparations and actual diving of the DSVs resulted in a greatly increased number of hours of work per day during the Dive phases, as well as during the Abort phase of Evolution I. In addition to these increased workloads, the decline in total sleep duration to 5 to 6 hours per 24 hour period during the Dive phases of both evolutions approaches the limit which was found to be the minimum sleep duration which could sustain performance in situations where sleep reduction was gradually and carefully controlled (Mullaney et al. 1977). Increases in the intersleep interval during Transit-Out indicated that the sleep pattern shifted from one major sleep period plus naps per 24 hours to a more lengthy pattern with an average of 19 (Evolution I) and 20 (Evolution II) hours from sleep onset to the next sleep onset with no naps between the major sleep periods.

Results of the NHRC Mood Questionnaire indicated that the Transit-Out and Dive phases were the most sensitive to mood variations. Consistent with the Sleep Log, the Mood Questionnaire reflects increased feelings of restedness and decreased fatigue during Transit-Out, while decreased restedness and increased Fatigue (negative mood disturbance) were more characteristic of the Dive, Dive-Abort, and Predeployment phases. However, the absolute magnitude of the mood scores generally remained within normal limits and the more conservative analysis showed Happiness (during Evolution I) and Fatigue (during the second and more demanding evolution) to be the major changing mood variables. Increases in Fatigue were most notable during the Dive and Predeployment phases, while it was least pronounced during Transit-Out.

Contrasting the two missions, the most salient mood difference was the consistently increased Anger noted during Evolution I. This variation was consistent with observational reports and appeared to correspond to the subject's dissatisfaction concerning an interrupted evolution, including an extended transit, additional workloads in foul weather, and no liberty in port. During both missions, it was also observed that though some subjects appeared angry, their test responses did not evidence increased mood disturbance, thus, the actual mood changes may have been more pronounced than those reported. Additionally, it should be cautioned that the results of the Geisser-Greenhouse test questions the reliability of many of the sleep and mood variations observed by adjusting for the possibility of correlated means among the many variables monitored within the same subjects. The weak consistency of mood changes between Evolutions I and II also suggests that any observed

significant mood changes (except for Happiness and Fatigue) are questionable.

During the missions there was no subjective evidence of performance impairment which would affect the ability of the DSV crews to successfully complete their task. Although the four-choice reaction time measures collected only for Evolution II tended to suggest that the number of performance errors increases during the mid and end phases of a dive, the predominance of rapid, stable, and correct responding was clear. Of interest were the increases in the standard deviation as well as mean values for the number of incorrect responses and gaps across dive phases. These appeared to suggest that not only do errors increase under fatiguing conditions, but also that only a few individuals, and not the crew as a whole, are likely to show critical decrements in performance.

Collectively viewed, the above mood trends, combined with the abrupt decreases in sleep duration, increases in workload, and decreased opportunities for recuperative naps would be expected to result in increasing fatigue, mood disturbance, and consequent impairment of performance had the missions been more demanding or of extended durations. Therefore, these data suggest that as DSVs are retrofitted for more lengthy and demanding dive missions, attention to scheduled rest or sleep periods will be necessary to prevent significant performance decrements, especially during the more critical and demanding dive phases (e.g., Dive and Dive-Abort).

Generally, decreases in core temperature, of which the above oral temperatures may be considered a reflection, are considered to be a function of both the length of the dive and the dive depth, since increases in dive time and depth show the ball temperature beginning to approximate the ambient sea temperature. Though all of the present measurements fell within acceptable limits, the trend of the data suggests that more lengthy dives in cold waters would create hypothermia hazards if careful attention is not given to thermal adjustments in the life support systems and/or proper clothing. Additionally, in interpreting the above temperature changes, it is important to consider that they may be somewhat complicated by circadian rhythms (Colquhoun 1971). The overall results suggest that a DSV mission of the present duration and difficulty, with a well experienced crew, can be accomplished without exceeding the capabilities of the crew and SSP. However, it

should also be noted that the demographic data indicated the present personnel have been well experienced. Less experienced personnel might be expected to have a lower tolerance for demanding conditions than these more experienced individuals. In addition, the raw data suggested considerable differences in individual tolerance for stress. This suggests an important role for crew selection and efforts toward identification of individuals who are particularly resistant or particularly sensitive to the effects of sleep loss and stress.

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TABLE I

EVOLUTION I

40 Days; 5 Dives

Dive Number	1	2	3	4	5
Length (Hrs)	5.05	2.5	5.65	6.4	6.03
Depth (Feet)	2301	2080	2773	2100	1850
Ball Temp./F	67-75	72-75	65-75	65-77	70

TABLE II

EVOLUTION I

Sleep Log and Stanford Sleepiness Scale

Variable	6 Days Transit-Out $\bar{X}$	6 Days Transit-Out SD	18 Days Non Dive $\bar{X}$	18 Days Non Dive SD	4 Days Dive $\bar{X}$	4 Days Dive SD	4 Days Abort $\bar{X}$	4 Days Abort SD	7 Days In Port $\bar{X}$	7 Days In Port SD	6 Days Transit-Back $\bar{X}$	6 Days Transit-Back SD	F df=5/55	p
Time to fall asleep (Min)	17.39	10.60	15.91	10.25	16.14	8.33	15.85	13.53	11.63	7.80	13.12	6.42	1.28	ns Δ
No. times woke up	1.07	.84	1.22	.59	1.11	.65	.83	.31	.73	.37	1.61	1.43	2.97	< .02 Δ
How well rested †	1.84	.45	2.22	.34	2.38	.41	2.38	.56	2.25	.65	2.26	.48	4.21	< .005 Δ
No. Hrs Worked/Day	6.30	2.85	8.12	1.58	12.17	1.23	12.38	2.01	8.62	1.73	5.80	3.08	31.29	< .001 **
Total sleep duration (Hrs)	7.42	.83	7.19	.74	6.16	1.13	5.89	.66	6.35	1.04	7.48	1.08	6.94	< .001 *
Inter-Sleep Interval (Hrs)	19.25	3.93	17.76	1.87	17.48	3.03	14.87	2.40	20.39	2.69	16.14	3.78	4.93	< .001 *
Stanford Sleepiness Scale (Range: 1 = alert to 7 = unable to remain awake)	2.34	.58	2.57	.46	2.78	.46	2.84	.71	2.63	.66	2.73	.76	1.90	ns Δ

Applying Geisser-Greenhouse: df = 1/1 ; * $p \leq .05$; ** $p \leq .001$; Δ = not significant.

† A high score indicates less rested and more fatigued.

TABLE III

EVOLUTION I

NHRC Mood Questionnaire

	6 Days Transit-Out		16 Days Non Dive		3 Days Dive		3 Days Abort		7 Days In Port		6 Days Transit-Back		F	P	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	df=5/55		
Activity	11.78	1.18	10.47	1.58	9.71	1.69	10.75	2.19	10.20	2.23	10.23	2.31	2.20	ns	Δ
Fear	9.37	1.84	9.50	2.02	9.97	2.43	8.81	2.46	9.02	1.74	7.96	1.92	2.27	ns	Δ
Happiness	13.68	1.98	11.68	2.33	11.67	3.24	11.89	2.46	11.48	2.91	12.62	3.02	4.85	< .001	*
Depression	7.40	1.19	7.95	2.11	8.12	2.50	7.22	1.57	7.60	2.10	6.98	1.01	1.52	ns	Δ
Anger	9.89	2.13	12.33	2.58	12.42	2.92	10.83	2.64	11.95	3.42	10.21	2.96	4.64	< .001	Δ
Fatigue	8.07	1.36	8.53	1.77	9.18	1.62	9.36	1.60	8.68	2.05	8.04	1.74	2.92	< .05	Δ

Applying Geisser-Greenhouse: df=1/11; * = $p \leq .05$; Δ = not significant.

TABLE IV

EVOLUTION II

34 Days; 10 Dives

Dive Number	1	2	3	4	5	6	7	8	9	10
Length (Hrs)	7.1	6.93	5.53	4.83	5.45	5.93	1.88	7.8	6.02	6.75
Depth (Feet)	6257	5691	3475	3477	5544	5836	2050	6125	6117	5796
Ball Temp./F	57-60	59-76	62-75	63-70	60-70	60-75	/6	., 70	60-64	58-70

TABLE V

EVOLUTION II

Sleep Log and Stanford Sleepiness Scale

	7 Days Predeployment		2 Days Transit-Out		10 Days Non Dive		9 Days Dive		6 Days In Port		F df=4/48	p
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$		$\bar{X}$	SD		
Time to fall asleep (Min)	11.46	7.83	13.31	8.88	10.81	6.08	11.06	6.09	11.52	10.05	.44	ns Δ
No. times woke up	.79	.80	1.38	1.36	1.15	.66	1.01	.69	1.42	.93	2.00	ns Δ
How well rested †	1.81	.60	1.62	.46	1.75	.57	2.18	.57	1.68	.39	5.37	< .001 *
No. Hrs worked/day	6.98	1.95	7.16	3.23	6.35	1.67	13.14	2.29	6.15	2.33	27.49	< .001 **
Total sleep duration (Hrs)	6.71	1.54	7.37	1.34	7.00	.97	5.20	.80	6.92	1.01	8.75	< .001 *
Inter-sleep interval (Hrs)	20.78	4.70	15.71	8.25	17.99	4.26	16.29	4.55	18.76	4.58	2.11	ns Δ
Stanford Sleepiness Scale (Low scores = less sleepy Scale of 1 = alert to 7 = unable to remain awake)	2.58	1.07	2.00	.68	2.29	.84	2.61	.78	2.34	.72	3.19	< .05 Δ

Applying Geisser-Greenhouse: df = 1/12; * $p \leq .05$; ** $p \leq .001$; Δ = not significant.

† A high score indicates less rested and more fatigued.

TABLE VI

EVOLUTION II

NHRC Mood Questionnaire

	7 Days Predeployment		2 Days Transit-Out		10 Days Non Dive		9 Days Dive		6 Days In Port		F	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	df=4/48	p
Activity	12.49	2.49	13.12	2.07	12.45	2.69	11.54	2.73	12.44	2.25	2.83	< .05 Δ
Fear	7.91	2.18	7.38	1.96	7.27	1.65	7.76	1.97	7.29	1.88	1.16	ns
Happiness	15.65	3.32	15.50	2.86	15.45	3.29	14.32	3.36	15.07	3.20	2.26	ns
Depression	7.45	2.45	6.88	1.97	7.15	2.09	7.07	2.18	7.11	2.26	2.53	.053 Δ
Anger	7.53	2.37	7.15	1.97	7.58	2.15	7.71	2.39	7.42	2.56	1.10	ns
Fatigue	7.10	2.15	6.15	1.66	6.60	1.71	7.29	1.75	6.36	1.46	5.00	< .005 *

Applying Geisser-Greenhouse: df = 1/12; * $p \leq .05$; Δ = not significant

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As deep submergence vehicles (DSVs) develop greater depth capabilities and are given longer duration missions, the physiological and psychological well-being of the operators and surface support personnel (SSP) becomes of increasing importance in insuring successful completion of the task. Establishment of baseline data on stress and fatigue in submersible operators and SSP is important in determining the safety of present operations and the reserve capability available in the event of unanticipated demands on performance. To obtain

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information on mood, fatigue, and work-rest cycles of both submersible operators and surface support crew members during actual operational dives in the open sea, 7 operators and 18 SSP were monitored during two separate multi-week evolutions using the DSVs TURTLE and SEA CLIFF. Operators and crew members lived aboard the surface support ship MAXINE D and 15 dives, some in excess of 6,000 FSW, were made. Demographic information, psychological, physiological and performance measures, and environmental data were obtained during pre-deployment, transit-out, dive, nondive, transit-in and post-deployment periods. The results suggested that disruptions in sleep-wake cycles caused by repetitive deep submersible operations may impair accuracy and efficiency on a variety of mental and physical tasks.